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by

David O. Hinton

Environmental Monitoring Systems Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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16. ABSTRACT Community air sampling ranges from simple infrequent measurement of individual pollutants to complex, continuous monitoring of multiple pollutants. To aid in planning a sampling program, suggestions are given with respect to purpose, site, location, sampling frequency, methods, Quality Assurance, and data retrieval. To aid in site selection and/or estimate historical air pollution levels, estimating techniques and their limitations are discussed. Limitations on the use/usefulness of fixed location, outside, air monitoring stations are discussed. The need for instrumentation to provide levels of individual ambient exposure is also discussed.		
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SECTION C
COMMUNITY AIR SAMPLING

David O. Hinton*

I. Introduction

A community air sampling program involves the collection of air pollution data from a well defined geographical area. The "community" may be a town, small city, suburb of a large city, or only a portion of an area geographically considered a community by nature of its topography. One or more sampling stations may be used within a community and several communities may be included in a given air sampling program. Community air sampling programs have ranged from simple, infrequent, manual (static or mechanized) monitoring of a few pollutants to the more complex, continuous, automated monitoring of many pollutants.

The basic objective of community air pollution monitoring is to determine concentration levels of one or more pollutants originating from any number of a variety of sources which are representative of the average exposure. Data from a community air sampling program may be used for different purposes: to determine the potential for detrimental effects to human health; to characterize economic loss through damage to vegetation, corrosion, etc.; to determine compliance with air quality standards, where the source of pollution may or may not be important; or to obtain further research data for models of the diffusion transport process. However, since the Clean Air Act uses human health effects as its justification for the primary air quality standard and vegetation effects as justification for the secondary standard, the better documentation of these effects should be considered as a desirable purpose for all monitoring.

Many air sampling programs are, or were originally, special short-term surveys or routine monitoring efforts that evolved with time into complete networks. Size of the area covered, number of samplers, types of pollutants monitored, frequency of taking samples, and time(s) over which the sample is averaged vary markedly from program to program and are dependent upon the specific program objectives moderated by resources available.

The contaminants or pollutants of concern also vary with local situations. Some are of such widespread concern as to be included in almost every community program. Particulate matter (suspended and/or settleable) and sulfur oxides were generally the first pollutants to be monitored. Both are important and widespread because of their source from the use of fossil fuels and from various industrial processes.

*Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711

Later, gaseous contaminants - i.e., nitric oxide, nitrogen dioxide, sulfur dioxide, photochemical oxidants (ozone, peroxyacetyl nitrate [PAN], etc.), carbon monoxide, and hydrocarbons - were monitored. These pollutants were frequently not included in earlier community air sampling programs because their significance has only recently become recognized and, to a lesser extent, because they generally require a more expensive sampling effort.

2. Planning A Community Sampling Program

A. Purpose of Measurement

The selection of a particular method for air pollution measurements depends upon both the specific goals for the monitoring and the sampling time requirements under current air quality standards. Early efforts in air monitoring, generally focused on providing air quality data for a variety of pollutants from a single central monitoring station. Measurements were usually made using mechanized sampling techniques and the pollutant concentrations were integrated averages for 24 hours or longer. Sampling was either performed daily or on randomly selected days of the year. Air quality information resulting from this type of monitoring provides information for the assessment of long-term trends and for enforcement of ambient air quality standards.

The sampling approach may be different in a given area because of the investigator's purpose. For example, measurements of major sources by a control agency may be approached by initially conducting a short-term, multiple-station, intensive survey for pollutants of interest, with subsequent reduction to one or two stations strategically placed to routinely monitor those areas experiencing maximum concentrations. Modification to the sampling strategy may be required as emissions increase (or decrease), control technology is applied, process emission characteristics change, or conversion to a different fuel is implemented.

Industry may take a different approach to ensure compliance with existing air quality standards. Managers of an industrial plant responsible for the control of a single pollutant may be most interested in integrated average concentrations from only their own source at different production levels for a short period of time. The plant's total monitoring effort may in fact be focused only on relating pollution concentration to production emissions as a basis for installing (or not installing) control devices.

In health effects studies, the origin and general distribution of pollution is no less important than in control. However, health effects studies require estimating exposure (i.e. concentration X time). This exposure must vary to determine different points on an exposure-response curve. For chronic effects

studies, locations of monitoring stations should be chosen to include high, intermediate, and low pollution exposure areas. For acute effects, the experimental design may only utilize temporal changes in one location. The areas for both types of study, however, must be well defined, and each specific monitor must be positioned to be representative of the immediate area.

B. Factors That May Affect Results

Many factors may affect the final results of an air monitoring program. Some of the more important considerations are discussed in the following paragraphs.

1. Location of Monitoring Site

Selection of a monitoring site requires many considerations. The effects of point sources, obstruction or changes to airflow caused by tall buildings, trees, etc., abrupt changes in terrain, and height above ground for the sampler or sampler probe will affect pollution values recorded at any given time. Practical considerations such as availability, cost, and accessibility of the site, together with the cost of providing electrical power, must also be included.

The importance of each of the above depends again upon the purpose for monitoring and whether or not sources are discrete or general. If the objective is to monitor carbon monoxide concentrations from vehicle exhaust within a city, one may specifically choose to obtain maximum concentrations by monitoring two meters above street level between tall buildings whose pockets allow concentrations to reach high values. In a valley community, local wind patterns, together with surrounding terrain, may allow temperature inversions that limit normal dispersion and create elevated levels of pollutant throughout the area, effectively trapping contaminants from local sources within the area. In both examples, measured values would be expected to be greater than for a larger, more generalized area.

Air monitoring in support of human health effects studies imposes the requirement that the resulting data represent exposure of the population group under study. Once areas are defined, it is desirable that stations be positioned to represent the entire defined area. Stalker, et al., (1) for example, indicated the need for continuous monitoring within 1 or 2 miles of the study population. His results also pointed to the differences of aerometric data obtained over community areas and the differences involved in random and systematic sampling schemes. Mobility of the population under an epidemiological study may require that area of residence, places of employment, local transportation routes, and schools attend be considered. Further refinement on exposure accuracy should be obtained by including both indoor monitoring and/or personal monitoring of selected participants.

2. Sampling Frequency and Averaging Times

Frequency of sampling ranges from infrequent sampling for discrete time intervals (e.g., one 24-hour sample every 13 days), to continuous readings taken as often as once per second. Limiting factors that may impact both sampling frequency and averaging times are instrument (sensor) performance and data retrieval techniques. Annual estimates are frequently based on random sampling using 24-hour integrated averages. Monthly or weekly trends may be determined based on daily averages, whereas peak, diurnal, and episodic information may require averaging times in hours or even minutes.

3. Methods Used to Measure Pollutants

Recommendations of specific methods or systems are not meaningful without identifying both the purpose and monitoring area; therefore, the reader is referred to the appropriate section or addenda dealing with instruments of interest. Any chosen measurement method, however, must be defensible in terms of accepted methods. Federal Reference Methods (and equivalent methods) exist for criteria pollutants (CO , O_3 , HC , NO_2 , SO_2 , TSP, Lead) as published in the Federal Register (48 CFR 50 and 40 CFR 53). Each Federal Reference Method is specified by a measurement principle, a set of performance specifications, and a calibration procedure. Because various methods may be used to measure a given pollutant satisfactorily, "equivalent methods" have also been designated by EPA after subjecting the candidate method to similar requirements specified for reference methods. Both "reference" and "equivalent" methods enjoy regulatory status and are available from any EPA regional office.

While EPA approved methods are required in some sampling programs (e.g., State Implementation Plans) the reader may choose alternate sampling methods based upon his own assessment of purpose, cost and reliability. The measurement techniques should be selected to provide known degrees of precision and accuracy in order that confidence levels can be placed upon the data obtained. A specific method may be acceptable for a 24-hour sample duration, but unreliable for 1-hour or 3-hour sampling periods because of insufficient sample for proper analysis. One procedure may be theoretically feasible for measurement of an isolated pollutant but completely invalid for measurement of a complex sample where secondary reactions would produce interference. Finally, one must consider whether the entire system should be manual, semi-automatic, or fully automatic.

Mechanized manual sampling methods, which include high volume samplers, gas bubblers, etc., have the advantages of being relatively simple, inexpensive, and reliable, but they may require an operator in attendance at the beginning and end of each sample period and also require subsequent laboratory analysis. For intermittent monitoring, long sampling periods, and studies of

short duration, a manual system may be indicated. For a large program, however, using a central analytical laboratory, the logistics of sample collection, equipment repair, and long turnaround time may make a manual method intolerable.

Semiautomatic systems that utilize continuous automated monitors improve upon the speed of obtaining data, but may not reduce the requirements for daily station attendance. These systems are more complex and expensive and generally require experienced, highly trained personnel.

Fully automatic systems with sophisticated automatic monitors and data processing systems give the advantages of remote monitoring and fast data retrieval. Although station operator attendance may be reduced, even greater technical competence is required because of system complexity. Duplication of essential equipment will reduce the possibility of missing data because of malfunction, but again costs would increase. Frequent calibrations and a system for expeditious equipment repair are essential in this type system to maintain high quality data.

4. Quality Assurance

An effective quality assurance program is an essential element of any environmental measurement system, since the data are subject to many sources of error. Beginning with written procedures and reference materials, all areas of a sampling program should be subject to quality assurance procedures. Hauser (2), for example, provides an overview of EPA's quality assurance activities in methods standardization, on site system surveys, site audits, ambient air and source measurements, development of quality control materials and standards laboratory operations. EPA's Environmental Monitoring Systems Laboratory, (EMSL) Research Triangle Park, N.C. 27711 maintains an on-going sample repository of both ambient air and station-ary source reference samples. These include liquids, gases, selected particulate fractions and organics. For more details, the reader is referred to Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I, EPA-600/9-76-005, March 1976.

C. Data Retrieval and Analysis

Manual collection methods generally require a chemical laboratory for manual or semiautomatic analysis (weighing, wet chemistry, etc.). Data are largely entered by hand with subsequent analysis eventually computerized.

For continuous environmental sensors, the classical method for gathering data has been the strip chart recorder. Although strip chart recorders provide accurate data, they require close attention and manual data retrieval with further manual or computerized data reduction.

Instruments are currently available that provide continuous analog or digital voltage outputs compatible with computerized data recording and processing for many pollutants. Use of these

instruments is increasing to meet the changing monitoring requirements of many state and Federal agencies. Individual instruments are selectively combined to meet the objectives of a specific system. One such automated data acquisition system, the Community Health Air Monitoring Program (CHAMP), was developed to meet the demands of EPA monitoring requirements for use in health effects studies (3,4). CHAMP had three major objectives for data retrieval and analysis:

- o Automatically and electronically collect and store sensor data at remote monitoring sites and retrieve the field data at any desired time by means of a central controller.
- o Visually observe on a display screen located at the central control station the operational parameters and data collection status for any given remote station desired.
- o Automatically process the retrieved field data with emphasis on machine validation of acquired data points.

There were two major components in the system: a field station that collected and stored data from various sensors on magnetic tape through the use of a minicomputer, and a central controller base station that retrieved data collected at the remote field station, flagged questionable data, and provided data analysis to determine precision and accuracy. The design was such that any number of field stations could be used, and flexibility of measurement parameters was provided.

For the normal mode of operation, data retrieval was performed automatically using a standard telephone network (telemetry) on command from the central controller. Field station information was recorded on a magnetic disk or computer-compatible magnetic tape and periodically transferred to the central controller via telemetry. Appropriate associated parameters and status signals (flow rates, valve positions, calibration constants, etc.) used for assessing system performance and for machine validation were also transmitted.

For a secondary mode of operation, of short duration where telemetry was not feasible, the field station collected data automatically in the normal fashion, but the magnetic tape record was physically delivered to the central controller base station where the information was processed in the normal manner. This reduced the need for telemetry, but increased the time required for data accessibility.

At the field station, in addition to automatic acquisition from sensors, data were entered on channels reserved for equipment status. This feature provided the capability for flagging questionable data by identifying any associated parameters that

may be outside predetermined limits and identified instruments that were in the process of calibration or out of service. Calibrations were traceable to National Bureau of Standards or EPA reference methods. Standardization of data analysis was designed to be compatible with available data from other sources. Formatting and identification parameters permitted access to the EPA National Aerometric Data Bank for obtaining related historical data or for data comparison.

D Estimating Past Air Pollution Exposure Data

In determining the long-term effects of air pollution, evaluation of historical air quality information has been utilized. Previous air quality information is useful in selecting a monitoring site and gives insight into how human pollutant burdens develop with time. Unfortunately, exposure data for the desired time period often are not available. Historical data are often for a single pollutant only. Furthermore, gaps of several years at a time may appear in the data. To make estimates of unavailable past air pollution levels, several techniques have been used. The techniques, described below, are admittedly cumbersome and time consuming and at best result in very generalized estimations.

1. Extrapolation or Interpolation Techniques

In some large metropolitan areas such as New York City, air quality data have been collected for a number of years. For example, an extensive survey of the geographical distribution of dustfall for the entire New York City area was made as early as 1944 (5). Dustfall data from 1955 - 1970 indicated that the ratio of annual average of suspended sulfate to the annual average of dustfall did not appear to change with time. This ratio has been used to estimate the values of suspended sulfate for those years in which dustfall data existed and suspended sulfate data did not. In other areas, total suspended particulate (TSP) versus dustfall gave a reasonable correlation. A plot of the ratio (TSP/dustfall) versus time for the Chicago area indicated a slight degree of time dependence (6). The reader is cautioned that this is a very rough estimating technique, but may be useful for site selection for new studies.

2. Modeling Techniques

Often, in smaller communities, air quality data may be available for only one or two recent years; therefore, techniques other than interpolation and extrapolation must be used for air quality estimates. Computerized air pollution meteorological models may be useful in making these estimations.

Where actual emissions data are not available, annual industrial production output together with a knowledge of the nature of the chemical processes may be used to calculate amounts of a particular pollutant emitted each year. Each particular industry

has associated with it a "standard manufacturing process" that indicates the typical set of production steps. The entire process produces, on the average, a given weight of specific air pollutants per unit of production in the absence of air pollution control equipment. If pollution reduction devices are employed, the weight of pollutant emission per unit of production is decreased in accordance with the efficiency of the equipment. From this production information, annual emissions can be estimated. A computer processing this information produces a map of isopleths that shows the annual average distribution of a particular pollutant in the community.

The following input information is required to operate a typical diffusion model program (7):

- o Annual wind roses for each year.
- o Weight of particular pollutant emitted each year.
- o Community area topography.
- o Frequency of inversions.
- o Depth of inversions.
- o Strengths of inversions.
- o Independent estimation of annual pollutant concentration for at least one year.

Accuracy of these techniques is dependent upon individual accuracies of each input parameter and decreases in direct proportion to the percentage of pollution originating from general sources because of the difficulty in quantifying their discrete effects. Continuing research into the diffusion transport process may increase the usefulness of air quality models.

3. Isopleths Based on Measured Pollutant Concentrations

Measurements of air pollutant exposure for some communities are available from many separate locations and extend back in time several years. Unfortunately, data from all stations are not available for every year. For example, for 1955, data from only 7 stations are available for the Los Angeles area; in contrast, data from 34 stations are available for 1972. Estimates of environmental exposures for communities where the air was not monitored can be made by constructing a set of pollutant concentration isopleths for each pollutant for each year by utilizing data obtained from nearby areas. The estimated pollutant values for the communities of interest can then be read directly from the isopleth maps. The isopleths are constructed by linearly interpolating the values observed at pairs of adjacent stations on a line connecting the stations. This process is repeated for all adjacent site locations except those where topographic con-

siderations, such as a mountain, would invalidate the interpolation. Pollutant concentrations at nearby locations external to the network of stations can be estimated through linear extrapolation. Smooth lines are drawn between locations of equal pollutant concentration. In cases where ambiguity exists concerning the detailed shape of a segment of the isopleth, more detailed interpolations and topographic analysis are required to resolve the problem (8).

E. Improved Measurement Instruments and Techniques

New and "improved" monitoring instruments are continually being developed. While many of these instruments represent true improvements, the reader is cautioned against premature acceptance of a given instrument. Reputable manufacturers usually prove the theoretical concept of the instrument through both laboratory and field testing, and for most applications the instrument is satisfactory. A specific evaluation by the user, however, is recommended. Instrument response, stability, and durability should be checked if the instrument is expected to operate under extremes of temperature, pressure, or humidity. Many equipment systems have failed to live up to expectations in air monitoring programs, generally because some components were not designed for continuous use. Instrument response to interferences should be quantified and compensated for. One study (9), for example, has shown that chemiluminescent oxides of nitrogen analyzers are not specific, but also respond to PAN, nitroethane, nitric acid, and other organic nitrates and nitrites.

In addition to improved instrumentation, large-scale studies have been developed to improve measurement techniques. The objectives of the Aerosol Characterization Study (10) conducted by the California Air Resources Board were: "to characterize the aerosol in California in terms of its physical and chemical properties, its interaction in the atmosphere and its natural and anthropogenic origins; to evaluate the amount of atmospheric aerosol in the study areas which can be related to primary emissions (i.e., auto exhaust or smoke stacks) and secondary production due to physical and chemical processes taking place in the atmosphere; to identify major sources of particles and chemically reactive gases which can be related to aerosol pollution and visibility; to estimate from aerosol source characterization in the study area the extent to which ambient air quality standards can be achieved by existing technology; and to evaluate the applicability of the aerosol analysis instrumentation employed in this study for use in present monitoring networks."

Another study, the largest, most comprehensive U.S. air pollution investigation ever undertaken, was EPA's Regional Air Pollution Study (RAPS) conducted in St. Louis, Missouri. It was designed to provide a better understanding of air pollution and better procedures for bringing it under control. Fixed stations contained analytical equipment to measure pollutants and meteorological conditions plus a minicomputer to acquire and transmit

data. Similar advanced electronic equipment was in mobile units on the highways and in helicopters that sampled at various altitudes. Aircraft photography, airborne radar, and related measuring devices also were used. A more complete description of the overall study is presented elsewhere (11).

When one considers improvements in the present state-of-the-art for monitoring human air pollutant exposures, one should think in terms of representing the true human experience of exposure. Except for special studies, past techniques involved the measurement of outdoor pollutant concentrations at fixed monitoring stations. These outdoor measurements were then used to relate health effects to the exposure experience of human subjects who, in fact, spend much of their lifetime indoors. The daily human experience may also involve traveling through an atmosphere where a person's exposure includes emissions from automobile traffic, industrial areas, and exposure to downtown shopping areas.

Present techniques for monitoring true exposures are not fully adequate to provide a complete diary of man's daily environmental exposure. More information is needed to describe the relationships between indoor and outdoor air pollution, and a need for methods to deal with these relationships in health effects studies is also apparent. To assume that the indoor environment is a function of the levels of outdoor contaminants would be misleading since pollutants are produced from indoor activities such as cooking, heating, and other everyday living habits of the household.

To determine individual exposure, miniaturized personal monitors should be used to provide researchers with exposure data to relate the living pattern of human subjects. Portable, personal monitoring devices have been extensively utilized by industrial hygienists and by those engaged in the measurement of occupational exposures. These devices are designed for the workman exposed to industrial concentrations, usually in confined areas. Although they are "portable," they are generally too large to be worn or carried by a study subject for long periods of time under routine living conditions.

New approaches are being considered. For example, a passive sampling device based on molecular diffusion of nitrogen dioxide gas has been designed for use as a personal monitoring device (12). Tests indicate that it is suitable for occupational exposure but will require 1-week exposure at ambient levels. Private companies such as 3M's Occupational Health and Safety Product Division, Dupont, MDA Scientific, Inc. and others, are developing commercial personal samplers for criteria pollutants and for some organic compounds. Considerable effort will be required to develop personal monitoring devices that will provide valid data for long-term and short-term human exposures in the ambient range. Recent innovations and miniaturization of sensor and electronic devices offer unique possibilities in this area (13, 14, 15).

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